Standard Recommended Practice for

MEASUREMENT OF AIRBORNE SOUND INSULATION IN BUILDINGS[1]

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INTRODUCTION

This recommended practice is one of a series for evaluating the sound insulating properties of building elements. It is designed to measure the performance of a partition element installed as a part of a building, whatever the configuration. Others in the series deal with the airborne sound transmission loss of an isolated partition element in a controlled laboratory environment, and with the laboratory measurement of impact sound transmission through floors.

The text has been prepared as an integrated whole. For the convenience of the reader it has been organized into eight sections and four appendixes. There is, in addition, a list of reference standards and papers.

1. Scope

1.1 *Measures of Acoustical Insulation*—This recommended practice establishes uniform procedures for the determination of *field transmission loss* (see 4.3, 4.4, and 4.5), that is, the airborne sound insulation provided by a partition (see Note 1) already installed in a building. It also establishes, in Appendix A1 a standard method for the measurement of the *noise reduction* between two rooms in a building, that is, the difference in average sound pressure levels in the rooms on opposite sides of the test partition. Where the test structure is a complete enclosure out-of-doors, neither the field transmission loss nor the noise reduction is appropriate; instead, a method is established for determining the *insertion loss*, also in Appendix A1.

Note 1—The word partition includes in its meaning partitions, walls of all kinds, floors, or any other boundaries separating two spaces, not necessarily enclosed. The boundaries may be permanent, operable, or movable. A ceiling-plenum-ceiling path (7)[2] is also included, though special efforts will be necessary to eliminate flanking transmission through the common wall (see Appendix A4). In this case, the results are comparable to noise reduction rather than to transmission loss.

Note that the noise reduction evaluates the effective acoustical isolation between a pair of adjacent rooms, whereas the field transmission loss refers only to the insulation which a partition interposes in the sound path through it.

1.2 *Types of Field Situation*—The conditions specified (**2**) for laboratory measurement of the transmission loss for airborne sound, in which the sound fields on opposite sides of the test partition are highly diffuse, very nearly conform to the mathematical model upon which the best available theory is based. Moreover, the greatest body of practical experience deals with transmission loss measurements under such conditions.

1.2.1 Unfortunately highly diffuse fields are not always found in the field; and, the special efforts which would be required to simulate laboratory conditions in the field are often impractical; in any case, they would vio-

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[2] The boldface numbers in parentheses refer to the references at the end of this recommended practice.

late the present meaning of a field test.

1.2.2 Instead, this recommended practice gives measurement procedures for determining the field transmission loss in nearly all cases that may be encountered in the field: no limitation to room-to-room transmission is intended. Thus, several different test procedures are given, each suited to a specific *type* of measurement situation; the appropriate measurement procedure must be selected for each field test according to the *type* of situation which that particular case most closely resembles.

1.2.3 Because it is well-known, the laboratory diffuse-field measurement procedure is described first in this recommended practice; an adaptation of the laboratory test method for use in the field being given in detail in the main body of the text (see Section 6). The alternative test procedures which will be required in field situations where diffuse sound fields do not exist on both sides of the test partition are given in Appendix A2, along with criteria for determining which alternative procedure is appropriate.

1.2.4 These alternative procedures are not interchangeable. In particular, it must not be expected that the alternative procedures will yield the same test values of field transmission loss. For example, the application of the different procedures to evaluate a given wall in place is likely to lead to results that do not agree, because only one of the procedures will be appropriate to that situation. On the other hand, if the same kind of partition is installed in two different locations and the appropriate test procedure is used for each case, the test results may not agree because the wall exhibits different attenuation characteristics depending on the incident sound field (see 3.3, 3.4, and 3.5).

1.2.5 Field transmission loss data should not be reported as conforming to this recommended practice for any field situation that does not conform to a type for which a measurement procedure is given in Section 6 or Appendix A2 (see 1.3 however).

1.3 *Intermediate Configurations*—Field configurations may be encountered which resemble but do not correspond exactly to one of the typical situations described in Section 6 or Appendix A2. For example, the receiving room absorption may be too great for the procedure of 6.1.3 (see 6.3) and too small for the procedure of A2.3 (see A2.3.3.2). In this case, measurements should be made using the procedures of both 6.1.3 and A2.3. If the results of the two test procedures differ by no more than 3 dB in any frequency band, the two sets of results may be averaged and reported as the field transmission loss, just as though the configuration had corresponded exactly to one of the types described above. In any case, the results of both measurement procedures must be reported. If the results of the two test procedures do not agree within the limits specified above, the test situation does not correspond to a type for which this recommended practice provides measurement procedures (see 5.1.3). The test data are likely to be unreliable and are not to be reported as the field transmission loss.

2. Summary of Method

2.1 The sound insulating property of a partition element is usually expressed in terms of the airborne sound transmission loss, which is the ratio, expressed in decibels, of the sound power incident upon the partition to the sound power transmitted through and radiated by the partition.

2.1.1 In the laboratory test procedure, this ratio is determined by mounting the partition between two reverberation rooms, one of which, the source room, contains one or more sound sources. The rooms are so arranged that the only significant sound transmission between them is through the test specimen. Under these conditions, the transmission loss is related, by a simple equation (2), to the space-time-average sound pressure levels in the two rooms, the area of the test partition, and the total absorption in the receiving room. When these quantities are measured in appropriate frequency bands, the transmission loss as a function of frequency is found.

2.1.2 The simplicity of that recommended practice depends on the provision of diffuse sound fields in both source and receiving rooms. When this situation is encountered in the field the procedure of Section 6 is to be used.

2.1.3 When one or the other (or both) of the test rooms is such that a diffuse sound

field does not exist there, different approaches must be used, as specified in Appendix A2.

2.1.4 In all cases, it is the goal of the recommended practice to determine the existing ratio of the power directly incident upon the test specimen to the power radiated directly from it.

2.1.5 Once the primary measurement of field transmission loss is complete, a supplementary test *must* be made to demonstrate that no significant flanking transmission is present. Details of suitable tests for flanking transmission are given in A4.5.

3. Significance

3.1 The problems of making reliable sound insulation measurements in the field are much more difficult than those met in the laboratory. In ordinary buildings, a great variety of test room shapes and sizes will be encountered; the amount of energy exchange at the nominal boundaries of the test specimen will vary widely; and there is often a problem of flanking transmission, that is, of sound arriving in the space on the receiving side of the test partition by paths other than the one directly through the partition. These variations influence the test results to a degree which is not predictable.

3.2 In principle, these same problems exist in laboratory measurements, but their influence is minimized by deliberately restricting the measurements to conditions with random sound fields on both sides of the partition, by the adoption of appropriate dimensions for the test chambers and for the test specimen, and by using special laboratory wall constructions to reduce the effects of flanking transmission (which may, in any case, be measured and evaluated once for all subsequent tests in each facility using the same specimen mounting (**2,3**).

3.3 In the field, on the contrary, the effect of the environment must be assessed for each measurement, and the difficulty of determining the field transmission loss will vary correspondingly. Indeed, it is possible that problems raised by flanking transmission or by an unusual field-test situation will make the measurement so difficult as to be impractical. *If this is so, it is preferable to acknowledge the fact outright*, instead of attempting to apply an inappropriate measurement procedure.

3.4 Evidently, there may be substantial differences between data obtained from similar structures in the laboratory and in a building, even when leaks and flanking transmission have been successfully eliminated. Since it is the purpose of the Field Transmission Loss Test to describe the performance of the partition in relation to the other elements of the building, no effort should be made to adjust the field data to laboratory values. Each field measurement will yield *a* field transmission loss, not *the* field transmission loss, of a partition type.

3.5 As more field measurements are made according to a standard procedure, the range of field transmission loss that may be expected for each partition type in various buildings will become clear. Indeed, it is likely that eventually a partition will be characterized as to its acoustical performance by two ratings: one dealing with the sound insulation which it provides, the other evaluating its expected variability under different conditions of field installation.

4. Definitions

4.1 *General*—This recommended practice follows the definitions and symbols of American National Standard Acoustical Terminology (ANSI S1.1) (**1**) and of American National Standard Method for the Physical Measurement of Sound (ANSI S1.2) (**20**). Some definitions of special relevance are repeated and certain usages are explained here:

4.1.1 *average sound pressure level* ($\bar{L}$) *in a room*—ten times the common logarithm of the ratio of the space-average mean-square sound pressure to the square of the reference sound pressure, the space-average being taken over the entire room volume with the exception of those regions where the direct radiation of the sound source or the near field of the boundaries (walls, furniture, etc.) is of significant influence (see 6.4, A2.2.8, and A2.3.4):

$$\bar{L} = 10 \log (p_1^2 + p_2^2 + \ldots p_n^2)/N p_o^2 \quad (1)$$

where:

p_o = the reference sound pressure, usually 20 $\mu N/m^2$ (0.0002 microbar); the refer-

ence pressure should always be stated;

N = the number of measurement positions (see A4.4.2), and

$p, p_2 \cdots p_n$ = the rms sound pressure at the N different measurement positions in the room; each p_n^2 should represent the energy in approximately the same fraction of the total room volume.

4.1.2 The average sound pressure level $\bar{L}$ is expressed in decibels. Detailed procedures for determining $\bar{L}$ are given in A4.4, 6.4, and 6.6.1.

4.2 *noise reduction* (*NR*)—the difference between the average sound pressure level in a room containing one or more sources of sound and that in another (usually adjacent) room. Calculate NR as follows:

$$\mathrm{NR} = \bar{L}_1 - \bar{L}_2 \qquad (2)$$

where:

$\bar{L}_1$ = average sound pressure level in the source room, and

$\bar{L}_2$ = average sound pressure level in the receiving room, both as defined in 4.1.1.

The noise reduction is expressed in decibels (see A1.1.2 and A1.1.3).

4.3 *field transmission coefficient* (τ_f)—that fraction of the airborne sound power, incident upon the source side of a partition installed in a building, which is transmitted and radiated into the receiving space. Calculate τ_f as follows

$$\tau_f = W_2/W_1 \qquad (3)$$

where:

W_1 = sound power (sound energy per second) incident directly upon the partition on the source side, and

W_2 = sound power radiated directly from the quiet side of the partition into the receiving space.

It is explicitly required that the symbols W_1 and W_2 represent steady-state, rather than transient, quantities.

4.3.1 In contrast to laboratory usage, where τ is defined only for diffuse sound fields, no restriction is made here as to the kind of sound field existing on either side of the partition. The field transmission coefficient will depend upon the kind of sound field incident on the specimen. It is the purpose of this recommended practice to identify the sound fields as well as possible in each case and to specify the corresponding appropriate procedure from which to determine the field transmission coefficient (and hence the field transmission loss) for this field situation.

4.3.2 For the purposes of this recommended practice, the power W_2 radiated from the quiet side of the partition may be less than the incident power W_1 because of (*1*) impedance mismatch (reflection of a portion of W_1 back to the source room due to either the mass or the stiffness of the partition); (*2*) energy losses due to damping within the partition or at the boundary; and (*3*) sound energy originally incident on the partition (and thus included in W_1) but leaving at the boundaries of the partition as flexural vibration (and thus not part of W_2). W_2 does *not* include energy flow from the other walls of the source room into the test partition and radiating from it into the receiving space; special efforts may be required to avoid this condition.

4.4 *flanking transmission*—transmission referring both to this last-mentioned component of power as well as to power traveling to the receiving space by paths in no way involving the test partition. Whether flanking transmission includes possible leaks around the partition depends upon the purpose of the test. A decision must be made as to whether the "leaks" are, or are not, a part of the partition (see 5.1.1, 5.1.2, and A4.5.5.5).

4.5 *field transmission loss* (*FTL*)—the acoustical isolation against airborne sound provided by a partition installed in a building; it is ten times the common logarithm of the reciprocal of the existing field transmission coefficient. It may be expressed as follows:

$$\mathrm{FTL} = 10 \log (1/\tau_f) = 10 \log (W_1/W_2) \qquad (4)$$

The field transmission loss is expressed in decibels.

4.6 *diffuse sound field*—a region containing many randomly oriented sound waves, with equal probability of energy flow in every direction; it follows that there is no correlation between instantaneous sound pressures at widely separated points.

4.7 *sound absorption of an enclosure* (*A*)—a measure of the property of an enclosure of absorbing sound power from the sound field it contains. The absorption of the receiving room may be determined (4) by means of the Sabine equation for the decay of sound in a room: if, following the discontinuance of a

sound source in the room, one determines the rate of decay of sound, then the absorption of the room, A, may be determined from the Sabine equation as follows:

$$A = (0.9210\ Vd)/c \qquad (5)$$

where:

c = speed of sound in air,
V = volume of room, and
d = rate of decay of sound following discontinuance of a sound source in the room, dB/s.

If V is in cubic feet and c is in feet per second, then A is given in sabins; if V is in cubic meters and c is in meters per second, then A is in metric sabins. This relation is derived on the assumption that the sound field is reverberant and diffuse, as in a reverberation room.

4.7.1 An alternative procedure is permitted, which depends on the relation between the sound power output of a source sounding in the room, the average sound pressure level, and the total absorption in the room (see 6.5.2).

4.8 *field sound transmission class* (*FSTC*)—a single-number rating derived in a prescribed manner from one-third-octave band values of sound transmission loss measured in the field. The rating provides an evaluation of the performance of a partition in certain common sound insulation problems. For its scope and the prescribed method of assignment see Ref. **(21)**.

4.9 *noise isolation class* (*NIC*)—a single-number rating derived in a prescribed manner from measured values of Noise Reduction. The rating provides an evaluation of the sound isolation between two enclosed spaces which are acoustically connected by one or more paths (see A1.1.3).

4.10 *field insertion loss* (*FIL*)—a measure of the sound isolation between two locations for which, because one of them is not enclosed, neither the transmission loss nor the noise reduction can be determined unambiguously. It is calculated as the difference formed by subtracting the sound pressure level at a location, shielded from a noise source by a barrier or enclosure, from the sound pressure level that would exist at the same location in the absence of the barrier.

5. Test Specimen

5.1 In this recommended practice, the special significance of a field test is that the test partition is to be measured just as it is found in the field. Nevertheless, some judgment must be used to ensure that the field conditions, as found, are consistent with the purposes of the test.

5.1.1 *Noise Reduction Test*—If the purpose of the test is to determine how much isolation the occupants of a certain pair of neighboring spaces are enjoying, then any peculiarities of the situation must be accepted as part of the existing isolation and no preparation of the test specimen is either needed or permitted. In this case, only the noise reduction is required; A1.1.2 specifies appropriate procedures for the measurement of noise reduction.

5.1.2 *Transmission Loss Measurement*—On the other hand, if the test is intended to demonstrate that the performance of the test partition complies with a specification, or if the test data are intended to determine the field transmission loss of a given field installation of the test partition (which data, taken together with other field data on nominally identical test specimens, will serve to typify the field performance of that partition type), then care should be taken to see that all conditions are "typical," and that the hazards of measurement are minimized, as specified in 5.1.3 below.

5.1.3 *Test Location*—Find a test specimen of the desired type in surroundings most suitable for the test, especially in cases involving acceptance testing of structures for conformance with sound insulation specifications. The two spaces which the test specimen separates should be selected on the basis of suitable size and shape, of absorption conforming to types described in this recommended practice (including Appendix A2), of freedom from structural irregularities near the test partition, of freedom from flanking, etc.

5.1.3.1 *Source Room or Receiving Room Very Small*—A serious difficulty arises in defining transmission loss in situations where either the source room or the receiving room is small compared to the wavelength of sound. In these cases, there is, strictly speaking, no radiation of the sound energy, but only a pul-

sating, quasi-static pressure throughout the room; hence, one cannot speak of "incident" or "radiated" sound power, and the transmission loss cannot be defined in the usual way. This situation will occur in any closed space if the frequency is low enough. A criterion is given (see 6.2.1 and Fig. 1) for determining the frequency below which the concept of transmission loss loses meaning. For frequencies below this limit, no attempt is to be made to determine field transmission loss, though the noise reduction may be measured and reported at these frequencies.

5.2 *Size and Mounting*—The size of the test specimen should be typical of the type of partition under study. Very small partitions sometimes yield different transmission loss values from similar large ones, and should not be used for test purposes unless the small size is characteristic of the construction being investigated; such an exceptional feature shall be made clear in reporting the results. Partitions 8 by 9 ft (2.4 by 2.7 m) or larger may be considered large enough that dimensional effects are not critical.

5.2.1 The mounting conditions of the test specimen should be representative of an ordinary and typical installation. Any unusual feature should be avoided unless this peculiarity is characteristic of the structure under investigation, in which case this fact must be stated clearly in all reports of the data.

5.3 *Flanking Transmission*—In many installations in the field, sound can arrive in the receiving space by paths other than that directly through the partition under test.

5.3.1 If the test is intended to determine the isolation actually existing between the spaces adjacent to the partition, no effort should be made to reduce the flanking transmission, since it is an intrinsic element of the existing isolation. If, however, the field transmission loss of the partition is to be determined, all significant flanking *must* be eliminated. A4.5.5 describes a mandatory procedure for ensuring that no substantial flanking is present.

5.4 *Drying and Curing Period*—Test specimens that incorporate materials for which there is a curing or drying process (for example, adhesives, plasters, concrete, mortar, damping compound) should age for a sufficient interval before testing. Aging periods for certain common materials are recommended in Section A1 of Ref (2).

6. Diffuse Sound Field Test Procedure

6.1 *Theory For Sound Transmission Loss:*

6.1.1 The theory for transmission loss in a diffuse-field was first developed by E. Buckingham (5,8,9). An ideal diffuse sound field is characterized by equal sound energy density at every point in the field and also by the condition that any small element of volume may be considered as a non-directional sound source radiating sound energy uniformly in all directions. Thus, in a diffuse sound field the individual wave packets of sound energy striking the test partition arrive with equal probability from all angles of incidence.

6.1.2 This treatment has been taken as the basis of ASTM Recommended Practice E 90, for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions (2). If a field situation is found to conform to the diffuse condition, as determined by the application of the criteria described in 6.2 and 6.3, test methods similar to the laboratory procedures may be applied. General requirements concerning instrumentation and test procedures are given in Appendixes A3 and A4.

6.1.3 If the test partition separates two rooms, each of which lends itself to the establishment of a diffuse sound field, the source room may be insonified by random noise from one or more loudspeakers to produce a diffuse sound field there. Some of this noise will be transmitted through the test partition to produce a diffuse field in the receiving room. The sound transmission loss of the test partition may then be derived from measurements in the two rooms according to the following equation:

$$\mathrm{FTL} = \bar{L}_1 - \bar{L}_2 + 10 \log S - 10 \log A_2 \quad (6)$$

where:

FTL = transmission loss in dB of the test partition; the prefix F is added to signify field measurement,

$\bar{L}_1$ = average sound pressure level in Room 1, the source room (see 4.1.1),

$\bar{L}_2$ = average sound pressure level in Room 2, the receiving room,

S = area of the test partition (in square feet or square meters), and

A_2 = total sound absorption in Room 2; if S is in square feet, A_2 should be expressed in sabins; if S is in square meters, A_2 should be expressed in metric sabins (see 6.5). Note that A_2 is the absorption with the test partition in place; sound transmitted back into Room 1 through the test partition constitutes part of the sound absorbed from Room 2.

In general, the acoustical properties of the partition and of the rooms are functions of frequency; make tests in a series of contiguous one-third octave bands of frequency between 100 and 5000 Hz (subject to the criterion for room diffusion of 6.2.1).

6.2 *Test Environment Defined*—Use the test procedures of Section 6 in the field if the environment conforms to the requirements of 6.2.1 and 6.3 below.

6.2.1 *Room Size:*

6.2.1.1 The measurement method of Section 6 requires diffuse sound fields on both sides of the test partition. The sizes of the source room and receiving room determine to a large extent (for a given measurement bandwidth) the lowest frequency at which the sound fields will be adequately diffuse: the larger the room, the lower the limiting frequency.

6.2.1.2 In laboratories, the test rooms are usually made large enough and are so treated that adequate diffusion is obtained at the lowest frequency of interest. In the field, however, where the room size must be accepted as given and may be small, the frequency below which a diffuse field will not exist (and below which the procedures of this section are, therefore, not valid) may limit the low-frequency range of measurement.

6.2.1.3 For suitable accuracy in determining the average sound pressure levels in the source and receiving rooms (see Eq 6), there shall be at least 10 modes per measurement bandwidth. Determine the lower limit of frequency for which this will occur, using one-third-octave bands, from the volume of the smaller of the two test rooms by reference to Fig. 1 (16).[3]

6.3 *Absorption of the Rooms*—The rooms will be suitable for the application of the test procedure of Section 6 if (in addition to complying with 6.2.1) the average (over all room surfaces) absorption coefficient is no greater than 0.25 at each test frequency for either room (see 1.3 (17)).

6.4 *Selection of Measurement Positions in Source and Receiving Rooms*—The sound pressure close to the walls of a room will be greater than that corresponding to the average energy density in the room (18). Therefore, for the measurement of the space-average sound pressure levels, $\overline{L}_1$ and $\overline{L}_2$ (see 4.1.1), locate the microphones preferably more than one-half and certainly no less than one-third wavelength from room boundaries or any other large reflecting surfaces, including the test partition. In addition, no microphone in the source room shall be in the direct field of a sound source. Directions for the manipulation of microphone systems are given in Section 8.6 of Ref (2)

6.5 *Measuring the Absorption of the Receiving Room*—Apply an adjustment involving the total sound absorption A_2 of the receiving room (see Eq 6) to the measured noise reduction between the source and receiving rooms in order to determine the field transmission loss of the partition. Measure this absorption either by the decay rate method (4), or with the aid of a reference sound source.[4] Make the determination of receiving room absorption with the receiving room in the same condition (except perhaps for the addition of a single sound source), and using similar microphone positions as the measurement of noise reduction.

6.5.1 *Decay Rate Method*—If the absorption of the receiving room is to be determined from the decay rate, follow the measurement procedure (4) summarized in 4.7. The test signal shall be the same, particularly with respect to bandwidth, as that used for the sound pressure level measurements.

6.5.2 *Reference Sound Source Method*—If a sound source is available whose power output L_w is known, calculate the value of 10 log A_2 in the receiving room from a measure-

[3] A curve is also given for octave-band measurements, for use with the test procedures of Appendix A2.

[4] The method of determining room absorption described by A. London (6)—which depends on measuring the sound pressure level as a function of distance from the test partition to determine the point at which the transition occurs from the (diminishing) direct field of the partition to the (uniform) reverberant field of the receiving room—is likely to be impossible or misleading in rooms having absorptive ceilings or floors, or both.

ment of the average sound pressure level $\bar{L}_p$ established there by the operation of the reference sound source (**10,11,12** and **22**). In a diffuse sound field, the sound power level $\bar{L}_w$ of a source, the average sound pressure level $\bar{L}_p$ in the room, and the total sound absorption A_2 of the room are related (**11**) as follows:

$$10 \log A_2 = \bar{L}_w - \bar{L}_p + 16.5 \quad (7)$$

or

$$A_2 = \text{antilog}\,[(\bar{L}_w - \bar{L}_p + 16.5)/10] \quad (8)$$

where:

reference power for $\bar{L}_w = 10^{-12}$W; and reference sound pressure for $\bar{L}_p = 20\ \mu N/m^2$ (0.0002 dynes/cm²).

6.5.2.1 The reference source may be a loudspeaker whose power output has been previously determined for a given electrical power input in each frequency band.

6.5.2.2 Alternatively, another sound source whose sound power output is constant enough for usable accuracy is a modified centrifugal fan (**11**) (See A3.5.1.9). For its power output level see Table A1.

6.5.2.3 Carry out the determination of absorption as a function of frequency in bandwidths the same as are used to measure sound pressure level differences.

6.6 *Interpreting the Data to Determine the Field Transmission Loss:*

6.6.1 *Level Readings:*

6.6.1.1 From the sound pressure level readings at several microphone positions in both the source and receiving rooms, determine the average sound pressure levels in the respective rooms in accordance with 4.1.1.

6.6.1.2 If the range of levels in each room is less than 6 dB, average the level readings in decibels directly. If the range for either room exceeds 6 dB, convert each observed level in that room to pressure-squared, average the several pressure-squared values, and reconvert the average pressure-squared to sound pressure level.

6.6.1.3 The difference between the space-average sound pressure levels $\bar{L}_1$ and $\bar{L}_2$ so obtained in the source and receiving rooms is the noise reduction defined in 4.2. (See A1.1.2.)

6.6.2 Determine the radiating surface area of the test partition in the receiving room with careful attention to the decision (see A4.5.5.5), as to what elements constitute the test specimen. This value of S is used, along with A_2, measured in consistent units as determined in 6.5, to adjust the sound pressure level differences of 6.6.1.3 to field transmission loss as indicated in Eq 6.

7. Reporting of Data

7.1 In contrast to the laboratory standard, this recommended practice standardizes the measurement procedures, but not the physical configuration for the test. Because the physical configuration cannot be standardized, careful reporting of the exact test conditions is necessary to permit a meaningful evaluation of the field test results.

7.1.1 *Statement of Conformation to Standard*—A statement is required, if it is true in every respect, that the tests were conducted in accordance with the provisions of this recommended practice. No data may be published as complying with this recommended practice, without indicating which procedure under Section 6 or Appendixes A1 or A2 was used. State the criteria for choosing that procedure, as well as the method by which they were established.

7.1.2 *Description of Test Configuration*—Give a complete description of the surroundings of the area in which the test is conducted.

7.1.2.1 *Description of Test Environment*—Give a sketch of the source and receiving spaces and their environs, showing both the plan of the test area and a section through the test partition. Give a description of the structures bounding the test partitions, including floor, ceiling, and wall structures of the source and receiving spaces.

7.1.2.2 *Furnishing of Source and Receiving Rooms*—Give a complete description of the furnishings of the test rooms adjacent to the test partition, noting the position with respect to the test partition of any bulky objects.

7.1.3 *Description of Test Specimen*—Give a complete description of the test specimen, including all of the essential constructional elements, the size, thickness,[5] and the average weight per unit area of the specimen.

7.1.3.1 The description of the test specimen should as far as practicable be based upon

[5] If there are no access panels, outlet boxes, etc., which would permit a direct measurement of wall thickness, one can often deduce the wall thickness by measurement between windows separated by the test wall.

measurement and examination of the specimen itself, rather than upon the building plans or information received from the builder or others.

7.1.3.2 State the composition of plaster mixes or plastic masonary applications, if possible, and also the surface finish and method of application. Report the drying or curing period, if any, and the final condition of the sample (shrinkage cracks, etc.). In the case of preformed panels, such as doors and office partitions, operable or not, specify the edge conditions in as much detail as possible. Report clearances around movable elements. If the construction or installation of the test specimen is, for some reason, such that the results do not represent normal performance of the specimen, state this fact explicitly.

7.1.4 *Nature of Test Signals*—Give a description of the type of test signals used in the measurements, both for absorption measurement and determination of level differences between source and receiving rooms, stating the bandwidth of measurement and the frequencies at which tests were made.

7.1.5 *Description of Test Procedure:*

7.1.5.1 Make a complete listing of the instruments used for the measurement. This should include the name, make, and type number of the instruments.

7.1.5.2 State the lower frequency limit of the test rooms as determined in 6.2.1. Field transmission loss shall not be reported for lower frequencies, though the noise reduction may be stated.

7.1.5.3 Give a complete description of the method of measurement by reference to appropriate paragraphs in this recommended practice, noting any exceptions.

7.1.5.4 If a reference sound source is used to measure room absorption, give a description and identification of this source, including the calibration for sound power level output.

7.1.6 *Background Noise Level*—Give the background noise levels in the receiving room in graphic form, in comparison with the actual average sound pressure levels observed during the transmission loss tests on both sides of the test partition. Give three curves on standard graph paper to the same scale as that on which the field transmission loss results are reported as described in 7.1.7 below.

7.1.7 *Statement of Test Results of Field Transmission Loss Measurement*—State the test results to the nearest 1 dB at the specified frequencies in tabular form and also show in graphic form on standard graph paper. State the measured total absorption in the receiving space, at each of the test frequencies (see Eq 8). Give the temperature and relative humidity in both test rooms.

NOTE 3—When the results are presented in graphical form, it is recommended that the ordinate scale be 2 mm/dB and the abscissa scale be 50 mm/decade. If it is necessary to use a larger or smaller scale, the same aspect ratio as above should be used. Whenever practicable, the ordinate scale should start at 0 dB.

7.1.8 *Statement of Qualifications to Accuracy of Test Results*—Taking into account all the available information about the field test, make a statement about the probable accuracy and reliability of the test results, and the extent to which the results of this test are representative of the partition type. Make special mention of unusual size of test partitions, unusual size or shape of the test rooms, or other irregularity which may be expected to make the measured results differ significantly from other field tests on the same type of partition.

7.1.9 *Comparison with Existing Laboratory Data*—A comparison may be made between the measured field data and any available laboratory data for nominally identical partitions. An explanation may be offered, if appropriate, of significant differences between the laboratory and field data (see A4.5.4).

7.1.10 *Field Sound Transmission Class (FSTC)*—For test partitions whose field transmission loss has been measured in one-third octave bands and for which, by applying the methods of A4.5, no significant flanking has been found to exist, a field sound transmission class (FSTC) may be assigned (**21**).

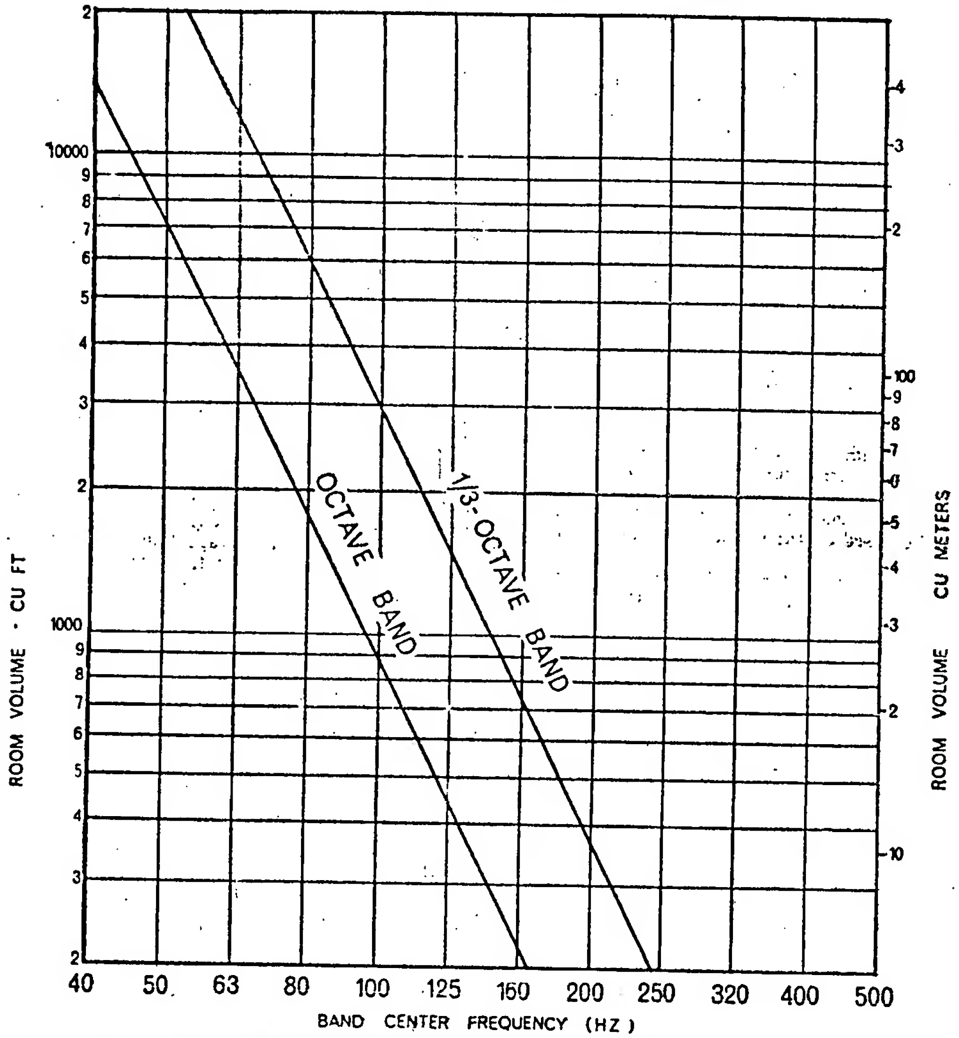

FIG. 1 Room Volume for Which There Will Be Ten or More Normal Modes per Measurement Bandwidth, Shown as a Function of Band Center Frequency, for Octave and One-Third Octave Bands.

APPENDIXES

A1. MEASURING NOISE REDUCTION OR FIELD INSERTION LOSS

A1.1 Isolation Between Rooms

A1.1.1 When the field transmission loss of the test partition is not at issue but one wants to know only how much isolation the occupants of the pair of rooms enjoy, the noise reduction should be measured. The test procedure for this quantity is identical to that given in Section 6 for determining the field transmission loss, except that no measurement is required of the receiving room absorption. Note that the noise reduction is associated with the two Test rooms, not with the dividing partition alone, and it may or may not involve flanking transmission.

NOTE A1—The general recommendations of Appendixes A3 and A4 shall be followed here, as applicable.

A1.1.2 *Noise Reduction*—Noise reduction is a measure of the isolation between two *enclosed* spaces, within each of which it is possible to determine the space-average sound pressure level. The difference between these average sound pressure levels is determined as described under 6.6.1.3 and is reported, with no further adjustment, as the noise reduction between the two rooms.

A1.1.3 *Noise Isolation Class* (*NIC*)—If a single-

number rating of noise reduction is desired, it shall be the noise isolation class (NIC), determined as follows. For field situations where the noise reduction between a pair of rooms has been measured in one-third octave bands, a single-number rating may be assigned to evaluate the acoustical isolation existing between these two rooms by applying to the measured curve of noise reductions the procedures of Ref. 21. No other single-number evaluation of noise reduction is sanctioned.

A1.2 Field Insertion Loss (FIL)

A1.2.1 *General*—When the test structure is a complete enclosure out-of-doors, surrounding either the source or receiver, it will be impossible to establish unambiguously an average sound pressure level in the outside space, and hence neither noise reduction nor field transmission loss has unambiguous meaning. In this case an appropriate measure of the isolation provided by the enclosure is the field insertion loss, measured either from outside the enclosure to inside or vice versa, as described below. The choice as to which is the appropriate procedure should be based on the intended purpose of the enclosure.

A1.2.2 *Outside-to-Inside*—For an external noise source, the field insertion loss is the difference formed by subtracting the average sound pressure level within the enclosure from the sound pressure level which would have existed there in the absence of the test enclosure. In measuring the field insertion loss from outside to inside the enclosure, the noise source should be located so as to simulate the sound field against which the enclosure is supposed to provide acoustical insulation. The sound pressure level which would have existed in the protected spot without the enclosure may be approximated by measuring the sound pressure level at the same distance, but in a different direction, from the source. (If the source is directional, it should be turned to face the microphone.) Care should be taken to avoid unwanted reflections from large near-by objects. The average sound pressure level within the enclosure should be measured as in 6.4 and 4.1.1. The Field Insertion Loss (FIL) is found from the following equation:

$$\mathrm{FIL} = L_d - \bar{L}_2 \qquad \text{(A1)}$$

where:

L_d = sound pressure level measured at the same distance, d, from the source as the center of the enclosure, and

$\bar{L}_2$ = average sound pressure level within the enclosure.

A1.2.3 *Inside-to-Outside*—On the other hand, if the enclosure is designed to confine the sound energy from some noisy source, the test procedure is similar in principle to that described in A2.3; but, since it is impractical to assign an effective radiating area for the test specimen (that is, the entire enclosure), the procedure of that section cannot be followed. To determine the field insertion loss, one can measure on the outside, at some arbitrary distance, the sound pressure level of the test source as attenuated by the enclosure; but, one must compute the sound pressure level that would have existed at the same point in the absence of the enclosure. This is done by determining the power output of the test source from a measurement of the absorption A_1 of the enclosure and the average sound pressure level within the enclosure; from this one can allow for spherical divergence (assuming small source dimensions) to calculate what the sound pressure level would have been at the outside measurement position if the enclosure were not there. The insertion loss is thus found as follows:

$$\mathrm{FIL} = \bar{L}_1 - L_d + 10 \log (A_1/16\pi d^2) \qquad \text{(A2)}$$

where:

$\bar{L}_1$ = average sound pressure level inside the enclosure,

L_d = sound pressure level measured at a point outside the enclosure a distance, d, from the center of the enclosure, determined by either of the procedures explained in 6.5, and

A_1 = total absorption within the enclosure.

If d is in feet A_1 should be expressed in sabins; and, if d is in meters A_1 should be expressed in metric sabins.

A2. TEST PROCEDURES FOR MEASURING TRANSMISSION LOSS IN NON-LABORATORY-LIKE CONFIGURATIONS

A2.1 General

A2.1.1 For certain field test configurations that do not conform to the requirements of Section 6, alternative test procedures are given in this appendix. For these procedures, as contrasted with that in Section 6, measurements in octave bands of frequency are permitted. The general recommendations of Appendixes A3 and A4 shall be followed as applicable, for the test procedures given here.

NOTE A2—None of these methods is exactly as described by A. London (6), whose equations depend to some extent on the equipment he used.

A2.1.2 In each case it is the goal of the test procedure to determine the existing ratio of the sound power *directly incident* upon the test specimen and the power radiated directly from it. A supplementary test, as described in A4.5 must be performed in each case to demonstrate the absence of any significant flanking transmission.

A2.2 Source Outdoors or in Highly Absorptive Space, and Reverberant Receiving Room

A2.2.1 When the source of sound is out-of-doors or in a highly absorptive space, sound power travels outward from the source as in a free field. Under these conditions the acoustical power incident on the test partition can be calculated from a knowledge of the sound pressure in the incident, nearly plane, wave.

A2.2.2 This test situation differs from that of Section 6 in that the sound is incident upon the test partition from only one direction for each sound source. In order to determine the field transmission loss unambiguously, therefore, the test procedure must utilize only a single sound source for excitation of the test panel. The transmission loss will usually be different for each angle of incidence of sound upon the partition; therefore, it is necessary to measure (by moving the source) and report the field transmission loss for several angles of inci-

dence between the normal (0 deg) and 75 deg away from the normal. Measurements for angles of incidence greater than 75 deg away from the normal are unreliable and are not recommended.

A2.2.3 To determine the sound pressure level L_1 associated with the incident wave, it will usually be most convenient to measure the average pressure $\bar{L}_{1,}$ at the face of the partition at several positions near the center and to subtract 6 dB to correct for the pressure doubling which will occur at this surface (unless the surface is acoustically absorbent, in which case see A2.2.8.3).

A2.2.4 On the receiving side of the test partition, the power radiated from the test specimen into the reverberant space is determined from a measurement of the average sound pressure level in the receiving room as in the procedure of Section 6.

A2.2.5 Under these conditions the field transmission loss is given as follows:

$$\mathrm{FTL} = \bar{L}_{1s} - \bar{L}_2 + 10 \log [(1/4) + (S \cos \theta / A_2)] \quad \text{(A3)}$$

where:

$\bar{L}_{1s}$ = average sound pressure level measured at the face of the partition on the source side, = $L_1 + 6$; and

θ = angle which the incident sound makes with the normal to the partition.

The other symbols are as described in Section 6.

A2.2.6 If the test structure is a complete enclosure out-of-doors, neither the transmission loss nor the noise reduction is appropriate; in this case refer to A1.2 for a procedure for determining the insertion loss.

A2.2.7 *Test Environment Defined:*

A2.2.7.1 *Receiving Room Size and Absorption of the Receiving Room*—The requirements for room absorption and for the lower limiting frequency for which diffuse conditions can be assumed to exist are the same, in the receiving room, as for the diffuse field procedures described in Section 6. Therefore, the restrictions of 6.2.1 and 6.3 apply here, with respect to the receiving room.

A2.2.7.2 *Absorption of the Source Room*—For the test procedure of this section to be valid, it is necessary that the pressure incident on the source side of the test partition be free of reverberant energy. Therefore, the average absorption coefficients of all the source room surfaces (except the test partition) shall be at least 0.75 (see 1.3).

A2.2.7.3 *Source Position*—It is also desirable that the sound wave be as nearly plane-progressive as possible. To this end, the (single) source of sound should be placed as far from the test partition as is consistent with keeping the entire partition within the direct field of the source and achieving the desired angles of incidence upon the test partition.

A2.2.8 *Measurement Positions:*

A2.2.8.1 *Receiving Room Side*—In the receiving room, measurements are to be made in the reverberant field. The procedure of 6.4 should be followed.

A2.2.8.2 *Source Side*—On the source side, measurements may be made at the face of the partition, if the source room side of the partition is highly reflective. For measurement of the average sound pressure level $\bar{L}_{1,}$ at the face of the partition, the microphone should be placed as near the partition as possible without actually touching the surface and without interfering with the sound field being measured. The diaphragm of the microphone should be oriented perpendicular to the surface of the partition. A single microphone on a long stick may be moved around over the face of the partition to determine an average level; or, the average may be calculated from several measurements at fixed positions.

NOTE A3—At frequencies between 2000 and 5000 Hz, only microphones of ½ in. (13 mm) in diameter, or less, will give accurate indications of the sound pressure level at the surface.

A2.2.8.3 *Alternative Method*—An alternative, indirect method of evaluating the sound wave incident on the surface of the test partition is useful when the surface is absorptive. The sound pressure level $\bar{L}_1$, corresponding to the incident wave alone, is measured out-of-doors or in an otherwise free field at the same distance from the source as the test partition (if the source is directional it should be turned to face the microphone); this level plus 6 dB is then used in place of $\bar{L}_{1s}$ in Eq A3.

A2.2.9 *Measuring the Absorption of Receiving Room:*

A2.2.9.1 The absorption of the receiving room may be measured by either of the methods described in 6.5.

A2.2.10 *Interpreting the Data to Determine Field Transmission Loss:*

A2.2.10.1 The average sound pressure levels on the source side and in the reverberant field on the receiving side, and their difference are to be determined by the averaging procedure of 6.6.1.2.

A2.2.10.2 The correction term involving the area of the partition and the absorption of the receiving room, is determined as in 6.6.2. The angle θ between the normal to the partition and the direction of the incident sound must also be measured and included in the correction term of Eq A3. A simple protractor will give a sufficiently accurate reading of the angle θ.

A2.3 Reverberant Source Room, Receiving Space Highly Absorptive or Outdoors

A2.3.1 In this case the sound power W_1 incident on the test partition is related, as in Section 6, to the space-average sound pressure level in the source room. The procedure of Section 6 cannot be used, however, for on the receiving side of the partition there is no reverberant field and hence no unique meaning to the space-average sound pressure level. For example, if the receiving space is outdoors, one could, by extending the distance of the measurement position indefinitely, find as low a sound pressure level as desired.

A2.3.2 Instead, the sound power radiated from the partition is assessed by measurements at close-in positions and the field transmission loss is determined as follows:

$$\mathrm{FTL} = \bar{L}_1 - \bar{L}_2' - 6 \quad \text{(A4)}$$

where:

$\bar{L}_1$ = average sound pressure level in the source room, and

$\bar{L}_2$ = space-average sound pressure level taken throughout a region near the test surface

(but not closer than a quarter wavelength) in the receiving space (8, 9).

A2.3.3 *Test Environment Defined:*

A2.3.3.1 *Source Room Size and Absorption of the Source Room*—The requirements for room absorption and for the lower limiting frequency for which diffuse conditions can be assumed to exist are the same, in the source room, as for the diffuse field procedures desci bed in Section 6. Therefore, the restrictions of 6.2.1 and 6.3 apply here.

A2.3.3.2 *Absorption of the Receiving Room*—The average absorption coefficient of the surfaces of the receiving space shall be at least 0.75 (see 1.3).

A2.3.4 *Measurement Positions:*

A2.3.4.1 *Source Side*—On the source side of the partition, the measurements should be made throughout the reverberant space to determine $\bar{L}_1$, following the procedures of 6.4.

A2.3.4.2 *Receiving Side*—The measurements on the receiving side should be made in a region near the surface to determine $\bar{L}_2'$ following the procedure of 6.4, except that no measurement position should be farther from the partition than half a typical partition dimension, nor closer than a quarter wavelength.

A2.3.5 *Measuring the Absorption of the Receiving Space*—In order for the procedure of this section to apply, the absorption in the receiving space must be high enough that the reverberant component of the sound field is effectively suppressed. Hence, it is not strictly correct to use methods for the measurement of absorption whose validity depends on the predominance of a diffuse field; this would eliminate both methods of 6.5. However, one needs to know only the *approximate* absorption in the receiving space to determine whether the environment qualifies for the test procedure described in this section; for this purpose the methods of 6.5 are suitable.

A2.3.6 *Interpreting the Data to Determine Field Transmission Loss:*

A2.3.6.1 The average sound pressure levels in the source and receiving spaces, and their corresponding difference, are to be determined as in 6.6.1. No correction for test partition area nor receiving room absorption is required; Eq A4 is used to determine the Field Transmission Loss.

A2.4 Both Source and Receiving Spaces Highly Absorptive: Plane Wave Both Sides

A2.4.1 In this situation, provided the source is far enough away, a plane progressive wave exists on both sides of the test partition. Where the source room is too small for this to be the case, judgment must be used to decide whether the maximum obtainable radius of curvature of the incident wave is such that the entire surface of the test partition is irradiated by a substantially plane wave, as required by the procedure of this section. When a plane wave is incident upon the test panel, an approximately plane wave may be assumed to radiate away from the panel on the receiving side. In terms of the sound pressure levels L_1 and L_2 in the incident and transmitted waves the field transmission loss is expressed as follows:

$$\text{FTL} = L_1 - L_2 \qquad \text{(A5)}$$

However, it will usually be difficult to determine L_1 directly, because of reflections from the insonified face of the panel; therefore, it is preferable (unless the panel face is absorptive) to measure the average sound pressure level $\bar{L}_{1_0}$ at the face of the panel on the source side and to subtract 6 dB to correct for pressure doubling as follows:

$$\text{FTL} = \bar{L}_{1_0} - L_2 - 6 \qquad \text{(A6)}$$

Alternatively, the method of A2.2.8.3 may be used to determine L_1 for use in Eq A5. Again as in A2.2 the field transmission loss should be determined as a function of the angle of incidence, θ.

A2.4.5 *Test Environment Defined*—The average absorption coefficients of all the surfaces of both source and receiving rooms (except the test partition) shall be at least 0.75 (see 1.3). The sound source should be located according to the recommendations of A2.2.7.3.

A2.4.6 *Measurement Positions:*

A2.4.6.1 *Source Side*—On the source side, the measurements should be made at the face of the partition, following the procedure of A2.2.8.2 or the alternative (free field) measurement of A2.2.8.3.

A2.4.6.2 *Receiving Side*—On the receiving side, the measurements should be made near the face of the partition, following the procedure given in A2.3.4.2 for $\bar{L}_2'$.

A2.4.7 *Measuring the Absorption of the Test Rooms*—The procedures of A2.3.5 should be followed to determine whether or not the field situation qualifies for use of the procedures of this section.

A2.4.8 *Interpreting the Data to Determine Field Transmission Loss*—The average sound pressure levels on both sides are to be determined for various angles of incidence (θ = 0 to 75 deg). No correction for partition area is required. The field transmission loss is determined from Eq A5 or A6 using $\bar{L}_2'$ as found in A2.4.6.2 for L_2, and $\bar{L}_{1_0}$ as found in A2.4.6.1.

A3. INSTRUMENTATION

A3.1 Microphones

A3.1.1 *General:*

A3.1.1.1 Microphones shall be stable and substantially omnidirectional in the frequency range of measurement. A condenser microphone with an associated cathode-follower as impedance transformer is preferred (because of its accuracy, stability and flat frequency response). Crystal or ceramic microphones are subject to a capable correction but may be used when the temperature is stabilized, or when the microphone system itself is temperature-stable. A stable wide-range dynamic microphone is also suitable. The microphone should be calibrated periodically throughout the test frequency range by a qualified laboratory technique (13).

A3.2 Microphone Amplifier

A3.2.1 For amplifying the microphone signal, either a stable microphone amplifier shall be used, or a sound level meter (14).

NOTE A4—In using American National Specification S1.4, General-Purpose Sound Level Meter (14), to meet the requirements of amplifying the microphone signal, omit reference to paragraphs pertaining to the "A" and "B" networks.

A3.3 Frequency Analyzers

A3.3.1 For the test procedure of Section 6, frequency analyses shall be made in one-third octave bands, particularly if it is expected that a field sound transmission class will be assigned. For very informal tests and for the procedures of Appendixes A1 and A2, full octave bands may be used. (There is an advantage in the use of octave-band filters when a diffuse field is required in either of the test rooms, since the wider band-width allows measurement to lower frequencies in rooms where the diffusion is limited by their small size (see 6.2.1)).

NOTE A5—All filters used for frequency analyses in the procedures of this standard shall comply with the requirements of Specification for Octave, Half-Octave and Third-Octave and Filter Sets (ANSI S1.11), for a Class II or BIII filter (15).

A3.4 Graphic Level Recorder

A3.4.1 A graphic level recorder may be used to record the sound pressure levels in the source and receiving spaces, provided that it complies with the requirements of Ref (14) for accuracy of rms readings. A calibration signal shall be recorded at the beginning and the end of each set of readings and all gain settings shall be noted on the graphic record.

A3.4.2 A graphic level recorder may also be used to record the decay of sound energy for the determination of absorption in the receiving room. At least 30 dB of the sound decay should be recorded, if possible. If this is not possible, the effective relation of signal to noise (in decibels) should be stated.

A3.4.3 The inherent decay rate of the recorder should be checked by rapidly shorting the recorder input while it is registering a near-full-scale input signal. The graphic record of this check should be retained. The inherent decay rate of the recorder (in decibels per second) shall be at least twice the decay rate of the sound in the test room.

A3.5 Reference Sound Source for Absorption Measurements:

A3.5.1 A reference (that is, constant output) sound source may be used to establish the total absorption in the receiving room. The reference source shall meet the following requirements:

A3.5.1.1 The sound from the reference source shall be broadband in character and without significant single-frequency components; the maximum sound pressure level of any single frequency component should be at least 10 dB below the octave-band sound pressure level.

A3.5.1.2 The sound power output of the source shall be great enough to comply with the requirements of A4.6 of this recommended practice.

A3.5.1.3 The mean square sound power output of the source shall remain constant (within ±1 dB) over an extended period of time.

A3.5.1.4 The source shall have a resilient mounting or shall be placed on a soft pad suitably designed to prevent transmission of noise and vibration to the structure on which it is mounted.

A3.5.1.5 The source shall be essentially non-directive.

A3.5.1.6 The source shall have a maximum short-term time-variation of sound pressure level for any octave band not greater than 2 dB (measured on the slow scale of a sound level meter).

A3.5.1.7 The source shall be physically small, of the order of 1 to 2 ft (0.3 to 0.6 m) maximum dimension.

A3.5.1.8 The reference source may be a loudspeaker; if so, it should be driven by (bands of) random noise and its total sound power output for a given electrical input shall be constant within the limits prescribed in A3.5.1.3 and in A3.5.1.6.

A3.5.1.9 Another acceptable form of reference sound source is a modified centrifugal fan, direct-connected to an induction motor with stable speed characteristics (11, 12). The sound power output level of this source as a function of frequency, when operated on the floor well away from walls and other large reflecting surfaces, is fairly constant; approximate average values are given in Table A1.

NOTE A6—Such a sound source is available from the ILG Electric Ventilating Co., 2850 N. Pulaski Rd., Chicago, Ill. The model number is ILG DSN 10910.

A3.5.1.10 The reference sound source shall be calibrated by a laboratory that is adequately equipped for the accurate measurement of sound power level on an absolute basis. A reverberant room method of test shall be used. See Section 3.5 of Ref (20). The sound power level calibration of the reference sound source shall be made in whatever frequency bandwidth is to be used for the analysis of sound in the measurement of field transmission loss; if the reference source is mechanical, any pertinent corrections for speed (line-voltage), temperature, barometer, etc., should be included.

A3.6 Sound Source(s) for Transmission Loss Measurements:

A3.6.1 One or more electro-acoustical sound sources shall be used to obtain the average sound pressure level difference for determination of transmission loss (or noise reduction or insertion loss). These sources may generate broadband or filtered random noise.

A3.6.1.1 The source(s) shall provide sufficient sound power at all frequencies to meet the requirements of A4.6 and A4.1.3.

A3.6.1.2 Directional loudspeakers should be avoided so as to minimize the danger of nonuniform incidence of sound on the test partition. The use of more than one loudspeaker may be necessary to generate a sound pressure level great enough to measure constructions with high transmission loss. High efficiency is more important than high fidelity in a loudspeaker for this application, though a smooth, flat (±5 dB, 100 Hz to 5000 Hz) frequency response is highly desirable.

A4. GENERAL TEST PROCEDURES

NOTE A7—Some of the instructions given in the procedures (such as those concerning the placement of loudspeakers and microphones) do not necessarily contribute to increased accuracy of measurement, but are prescribed arbitrarily so that independent investigators will be more likely to arrive at the same numerical results.

A4.1 Generation of Sound Field on Source Side

A4.1.1 *Sound Source(s)*—The sound source shall be one or more loudspeakers, driven with adequate electrical power to satisfy the requirements of A4.1.3 and A4.6 and with any type of signal described in A4.2 below.

A4.1.2 *Sound Source Position(s)*—Place each loudspeaker in or near a trihedral corner of the room in order to excite as many room modes as possible. (This recommendation holds for most procedures; exceptions may be necessary in certain situations.) Select the room corners in which the loudspeakers are to be placed as follows: if one stands with his back to the test partition in the source room, place the first loudspeaker on the floor in the far right-hand corner; the second on the floor in the far left-hand corner; additional loudspeakers, if used, should be evenly spaced on the floor between the first two. If, for some reason, this convention cannot be followed, this fact should be noted and the position of the loudspeakers should be described in the test report.

A4.1.3 *Source Room Level*—The sound pressure level in the source room should be great enough to provide a signal level in the receiving room at least 10 dB above the background noise level in the measurement band at all test frequencies (background noise means here the combination of acoustical and electrical noise, see Section 1.26 of Ref. (**1**)). Since this condition will usually be most difficult to achieve at low frequencies, the speaker should be capable of radiating the lowest test frequency efficiently.

A4.2 Test Signals

A4.2.1 *Signal Spectrum*—The source-room sound signals used for these tests shall form a series of bands of random (Gaussian) noise containing an essentially continuous distribution of frequencies throughout each test band. "Pink" noise, comprising random noise of equal power per fractional bandwidth (throughout the frequency range and also within each band) is recommended. These signals may be generated in the field with a random noise source and filter set (separate from the analyzer filter) or may be prerecorded on magnetic tape for reproduction in the field.

A4.2.2 *Test Frequencies*—Select the nominal test frequencies (subject to the criterion for room diffusion of 6.2.1) from the following series: 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, 4000, and 5000 Hz. Use contiguous test bands, so that data are obtained for all frequencies within the chosen range. Pure tones shall not be used, since they give rise to large fluctuations in the sound field which are strongly dependent on frequency and position.

A4.2.3 *Bandwidth*—The bandwidth of each test signal except for informal tests, shall be one-third octave for the procedure of Section 6. For the procedures of Appendixes A1 and A2, either octave or one-third octave bands may be used. The over-all frequency response of the electrical system, including the filter or filters in the source and microphone circuits, shall for each test band conform to specification for Octave, Half-Octave and Third-Octave Band Filter Sets (ANSI S1.11), for a Class II or III filter (**15**).

A4.2.4 Filtering may be done either in the source or microphone system or partly in each, provided that the required over-all characteristic is achieved. Apart from defining the bands of test signals, a filter in the microphone system serves to filter out extraneous noise lying outside the test band, including possible distortion products in the source system; a filter in the source system serves to concentrate the available power in the test band.

A4.3 Sensitivity Check

A4.3.1 Carefully check all instruments at the time of the tests. This is particularly important in field measurements where the hazards of transportation increase the likelihood that the equipment will be found out of adjustment at the test site.

A4.3.2 When source room levels and receiving room levels are to be measured with the same instruments, perform sensitivity checks before beginning the measurements in each room and at intervals during the test, to assure drift of not more than 0.5 dB.

A4.3.3 When two sets of sound level measuring equipment are used for measurement of sound levels in the source and receiving rooms, check the sensitivity of both sets before field tests are begun and at intervals of not more than 30 min thereafter. Use the same calibration equipment for all calibrations. The microphones must all be of the same make and model.

A4.3.4 Make the sensitivity check of the microphone(s) using an acoustic or electrostatic calibrator which has electronic drift of not more than 0.5 dB in a day. The sensitivity check shall usually consist of impressing a known sound pressure upon the microphone and noting the unfiltered electrical output of the entire microphone system, keeping account of all variable gain settings in the equipment. This establishes a sensitivity in terms of which all subsequent electrical outputs, filtered or not, can be converted back to sound pressure levels at the microphone, taking account of the filter response and any changes of gain in the system.

NOTE A8—A nominal sine wave having less than 10 percent distortion and unvarying amplitude to within 0.1 dB is recommended.

A4.3.4.1 If only relative levels are required (for example, if the same system is used in both source and receiving rooms, and the absorption of the receiving room is determined from the decay rate, rather than from the absolute levels established by a reference source), a check is needed only to assure that the over-all sensitivity remains constant throughout the test. Carry out the checking procedure in such a way as to eliminate errors caused

by variations in response between microphones when used in reverberant sound fields.

A4.3.5 The sensitivity check in the field need be made at only one frequency within the range from 200 to 1250 Hz.

A4.3.6 Include the entire measuring set-up (including the microphone, all cables, and instruments) in the check for sensitivity. Recheck the entire set-up after any changes, adjustments, or substitutions of cables or equipment.

A4.4 Sound Pressure Level Measurements

A4.4.1 *Averaging Time*—For each sampling position, the averaging time shall be sufficient to permit an accurate estimate, from observations of a sound level meter or a graphic level record, of the time-average sound pressure level.

A4.4.2 *Number and Precision of Measurements*—One or more microphones, or a single moving microphone may be used to determine the average sound pressure level in the test rooms. If only one or two microphones are used, the average may be obtained by moving them to several different stations in the rooms. If a large number of microphones are used at different stations in the rooms, their outputs may be observed consecutively by switching between microphones.

A4.4.3 It is not recommended that the electrical outputs of two or more microphones be combined. However, if the averaging is done by combining outputs electrically, the following precaution must be taken: squared outputs, rather than linear outputs, must be combined; the microphones must be matched in sensitivity within 1 dB over the frequency range of interest.

A4.4.4 Use a minimum of five measurement positions (see 6.4), but make measurements at enough positions that the standard deviation of the mean of the N readings in each frequency band is less than 2.0 dB, defined as follows:

Standard deviation =

$$\sqrt{(\Sigma_n (L_n - \bar{L}_n)^2)/(N (N - 1))} \qquad (A7)$$

For convenience in making this calculation, $\bar{L}$ may be computed from $(\Sigma_n L_n)/N$. However, the average $\bar{L}$ to be used in calculating field transmission loss must conform with the definition in 4.1.1.

A4.4.5 *Measurement Filters*—Where the bandwidth of the sound source is greater than the desired analysis bandwidth, or where it is necessary in order to meet the requirements of A4.1.3, analyzing filters must be used in the measuring equipment. These filters must conform to the requirements of A3.3. Use the same filters to measure both the absorption in the receiving room and the average sound pressure levels in the test spaces.

A4.5 Checks for Flanking Transmission

A4.5.1 In measurements where the field transmission loss of the test panel is required, rather than just the noise reduction, reduce flanking transmission to a negligible amount so that the measured levels in the receiving room correspond to only that sound which is transmitted through the partition under test. The following procedures may be used to determine whether or not significant flanking exists. Note that the flanking test of A4.5.5 is mandatory.

A4.5.2 The first and simplest check is to walk around the receiving room and, listening either with a stethoscope or with the unaided ear, try to detect obvious leaks, where sound is entering the space by way of unintended paths.

NOTE A9—A word of caution is in order concerning the use of a stethoscope to detect leaks: ordinarily the diaphragm head of the instrument is removed and one probes with the open end of the tube into corners and along edges where leaks are suspected. As the tip of the tube is moved into a corner, one usually hears an increase in sound level at high frequencies due to "pressure doubling" near boundaries and corners; this effect should not be mistaken for a sound leak.

A4.5.3 One may also investigate whether the surfaces of the receiving room other than the test partition are vibrating significantly at the frequency of the sound source; an accelerometer may be used to compare the vibration of the test partition with that of other surfaces. The average vibration level of each of the other room surfaces should be at least 10 dB below that of the test partition.

A4.5.4 After the transmission loss calculations have been made, compare the resulting field data with laboratory transmission loss data for a similar type of partition. One should not necessarily expect close agreement, but widely divergent trends may indicate the existence of flanking paths, of leaks, or of deviations from the nominal construction of the test specimen.

A4.5.5 Perform the following test, for all field transmission loss measurements in accordance with the procedures of Section 6 and Appendix A2, to demonstrate the absence of significant flanking transmission:

A4.5.5.1 After the ordinary measurements have been made to determine the field transmission loss add a special temporary shield (see below) to the test partition to increase its effective transmission loss. Then repeat the measurements. If the measured values of transmission loss change as a result of the added skin by at least 3 dB, assume that no significant flanking exists. If this is not the case, then locate the flanking paths and correct.

NOTE A10—An alternative procedure (which is more difficult but may help eliminate existing flanking paths in addition to detecting their presence) is to add a second skin to all four boundaries (the side walls, floor and ceiling) adjacent to the test specimen and remeasure the average sound levels. In this case, any change in measured results is usually an indication that flanking transmission present in the original test has been reduced.

A4.5.5.2 Clearly identify all data for which the flanking transmission cannot be effectively eliminated in the report, but it may be stated that the field transmission loss is at least as great as the flanked data indicate.

A4.5.5.3 A convenient means of adding the supplementary skin is to support pieces of ½-in. (13-mm) gypsum board or plywood in front of the test panel at a distance of about 6 in. (152 mm).

NOTE 11—It may be convenient to arrange the panels in a splayed, zig-zag configuration so that, when the edges are taped, the array is free-standing, like a decorative screen.

A4.5.5.4 The total projected surface area of the added skin should be slightly smaller than that of the test panel itself. Seal all internal joints of the skin by taping. Distribute a substantial amount of sound absorbing material evenly throughout the air-space between the skin and the test panel. To form a seal around the edges of the skin, tape strips of heavy (½ lb/ft²) flexible sheeting (such as lead-filled vinyl plastic or sheet neoprene) to the edges of the skin and also the walls bounding the test partition.

A4.5.5.5 Take care that the area thus shielded comprises all of, but no more than, the structural elements making up the specimen under test. For example, in the case of an operable or demountable partition, it is usually understood that the manufacturer has the responsibility of providing an adequate seal to the surrounding structure; this seal, therefore, is part of the specimen under test. In this case, tape the supplementary skin just *outside* the seal, so that the seal is covered (as part of the specimen) for the second measurement.

A4.5.5.6 The supplementary skin may be added on either side of the test partition, but if it is applied on the source side, there is no need to remeasure the absorption in the receiving space.

A4.6 Check for Background Noise

A4.6.1 Make a check at the beginning and end of each test for electrical and acoustical background noise by measuring the sound pressure level in the receiving room in each frequency band used for the transmission loss tests. Make this measurement with no modification of the test setup or test room, except that the sound source shall be turned off. If the sound pressure level measured with the source operating is at least 10 dB greater in each frequency band than with the source silent, the error in the test measurement due to background noise will be less than ½ dB.

A4.6.1.1 *Correction for Ambient Sound Pressure Level*—If, in any frequency band, the average sound pressure level in the receiving room with the sound source operating exceeds the ambient sound pressure level by only 4 to 10 dB, the observed receiving room levels are likely to be in error. The true sound pressure level due to the sound source alone may be approximated by applying to the measured levels the corrections listed in Table A2. These corrections are based on the assumption that the indicating meter responds to root-mean-square (rms) sound pressure, but they are approximately applicable to the indicating instruments used in standard sound-level meters. It is further assumed that the ambient sound pressure and the sound pressure due to the sound source are incoherent and can, therefore, be added on a "pressure-squared" basis. If the contributions from the sound source and the ambient noise are coherent, phase relations are important and corrections in general terms cannot be stated.

A4.7 Measuring the Damping of the Partition

A4.7.1 For some types of partition there is a strong influence of partition damping on the observed transmission loss. Although this exact relation is not yet well understood, it is desirable that data on in-place partition damping be collected for later reference and study. Accordingly, this recommended practice encourages, but does not require, for each test specimen whose transmission loss is measured in the field, a measurement of the damping (loss-tangent) as a function of frequency (19).

A4.8 Temperature and Relative Humidity

A4.8.1 Take wet- and dry-bulb temperature readings in both source and receiving rooms. Calculate and report the relative humidity for both rooms.

TABLE A1 Power Output of an Average ILG Source in a Reverberation Room

NOTE—The ILG source must rest on the bare floor, at least a half-wavelength away from other reflecting or absorptive surfaces. No cover, grille, or shroud should be attached to the fan.

Band Mid-Frequency, Hz	Sound Power Level (Diffuse Field)[a] dB re 10^{-12} W	
	One-Third Octave Band	Octave Band
40	69.0	
50	70.0	
63	70.5	75.5
80	71.0	
100	71.0	
125	72.5	77.5
160	74.0	
200	74.0	
250	75.0	79.5
315	75.0	
400	75.0	
500	75.5	80.0
630	75.0	
800	75.0	
1000	75.5	80.5
1250	76.0	
1600	76.0	
2000	76.0	80.5
2500	75.5	
3200	75.0	
4000	74.0	79.0
5000	74.0	
6300	74.0	
8000	73.0	77.5

[a] The values which appear in this table represent the average of several measurements of the ILG source in reverberant rooms. Measurements in a free-field, however, yield results which exceed the tabulated values by as much as 8 dB at frequencies below 200 Hz. These differences are attributed to a reaction of the room upon the source.

Attention is called to these differences because the (higher) free-field values may be cited in other standard test procedures. For the purpose of this document, the reverberation room data are appropriate, since the aim is to determine the total absorption in a quasi-reverberant space. On the other hand, if the aim is to determine, by means of a reverberation room comparison of an unknown with a reference sound source, the total sound power which would be emitted out-of-doors, the free-field ILG data would be used.

TABLE A2 Corrections for Ambient Sound Pressure Levels

	dB						
Difference between sound pressure level measured with sound source operating and ambient sound pressure level alone	4	5	6	7	8	9	10
Correction to be subtracted from sound pressure level measured with sound source operating to obtain sound pressure level due to sound source alone	2.2	1.7	1.3	1.0	0.8	0.6	0.4

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